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VALE (AUSTRALIA) P P ELISCHER SEP 86 NAL-R-1020

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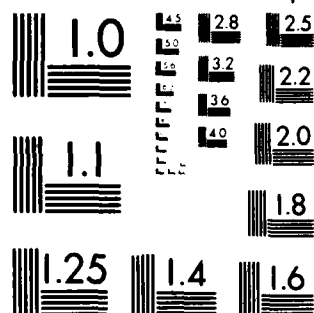
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DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
MATERIALS RESEARCH LABORATORIES
MELBOURNE, VICTORIA

REPORT

MRL-R-1020

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THE DEVELOPMENT OF LOW COST 155 MM PRACTICE
AMMUNITION: A FEASIBILITY STUDY

P.P. Elischer

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SEPTEMBER 1986

**DEPARTMENT OF DEFENCE
MATERIALS RESEARCH LABORATORIES**

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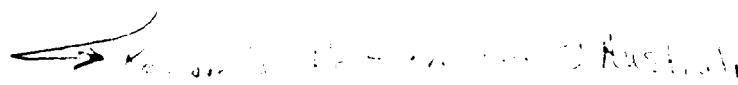
P.P. Elischer

ABSTRACT

Ammunition collectively termed practice ammunition is available in a multiplicity of designs suitable for use in a wide range of service ordnance. Ammunition used for practice contains live components and is designed to inflict minimum damage to or at the target. It is used primarily to reduce costs associated with using operational ammunition for maintaining those skills acquired during initial training programs.

This report investigates the feasibility of producing locally a low cost purpose designed practice projectile to be used by the Medium Gun Regiment for training with 155 mm howitzers. The overall aim was to review the current processes for manufacturing high explosive filled projectiles and then to identify those processes which might not be necessary for the manufacture of practice projectiles, thereby reducing production costs.

Two configurations, one utilizing production shell bodies filled with high explosive substitute and the second based on a hollow shell, are discussed. Both configurations are considered suitable as practice projectiles with potential cost savings, when compared with the operational round, of 30% to 50%. Empirical trials demonstrated the feasibility of using small spotting charges to provide the required aural and visual signatures necessary for effective artillery practice.


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**POSTAL ADDRESS: Director, Materials Research Laboratories
P.O. Box 50, Ascot Vale, Victoria 3032, Australia**

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DOCUMENT CONTROL DATA SHEET

REPORT NO.
MRL-R-1020AR NO.
AR-004-837REPORT SECURITY CLASSIFICATION
Unclassified

TITLE

The development of low cost 155 mm practice
ammunition: a feasibility study

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CORPORATE AUTHOR

Materials Research Laboratories
P.O. Box 50,
Ascot Vale, Victoria 3032REPORT DATE
September 1986TASK NO.
ARM 84/016SPONSOR
ArmyFILE NO.
G6/4/8-3133REFERENCES
7PAGES
24

CLASSIFICATION/LIMITATION REVIEW DATE

CLASSIFICATION/RELEASE AUTHORITY
Superintendent, MRL
Physical Chemistry Division

SECONDARY DISTRIBUTION

Approved for Public Release

ANNOUNCEMENT

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KEYWORDS

Projectiles
AmmunitionExplosives
Heat treatment

High explosive

COSATI GROUPS 19010

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This report investigates the feasibility of producing locally a low cost purpose designed practice projectile to be used by the Medium Gun Regiment for training with 155 mm howitzers. The overall aim was to review the current processes for manufacturing high explosive filled projectiles and then to identify those processes which might not be necessary for the manufacture of practice projectiles, thereby reducing production costs.

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THE DEVELOPMENT OF LOW COST 155 MM PRACTICE

AMMUNITION: A FEASIBILITY STUDY

1. INTRODUCTION

Army have recently replaced their 5 inch medium gun, used by the medium support regiments, with the US manufactured M198, 155 mm howitzer. The 155 mm was chosen for reasons of standardization with both British and American artillery requirements. The M198 is able to fire both UK and US ammunition, as well as developmental munitions being manufactured in other NATO countries.

To complement their short term training requirements, Army has bought a number of US M107 HE projectiles. At the time of purchase these were readily available and relatively inexpensive; the unit cost excluding propellant charge and fuze was around \$150-\$200. In the long term, Australia may use the British L15A1 family of projectiles with the L15A1 HE projectile being manufactured in Australia under licence. The estimated unit cost of this projectile, excluding propellant charge and fuze, is \$900 if purchased from the UK and about \$600 if manufactured in Australia. A further cost of \$600-700 is required to cover the manufacture of propellant charge, fuze and igniter tube. These cost estimates were based upon 1983 figures.

Training use of the M107 HE projectile is limited because it differs in shape and weight from the L15A1 projectile. Consequently they do not ballistically match the flight characteristics of the L15A1 nor do they have the same range capabilities. The use of the M107 HE projectile for training would therefore necessitate a different set of range firing tables and Field Artillery Computer Equipment (FACE) software than is currently used for the L15A1 projectile. Present indications are that Australia has sufficient M107 HE projectiles for service requirements until the late 1980s, after which time the L15A1 HE projectile could become operational. There was initial Army interest in the continued use of the M107 HE projectile for training purposes only, because of its low cost. However, US manufacture of the M107 HE round has now ceased. To restart the production line to produce the quantity necessary to meet the Australian Army's training requirements would not be viable as the cost of each M107 round could now be as high as \$3000 per unit.

Army is concerned about the cost of artillery training, not only for their recently acquired 155 mm howitzer, but also for other calibre guns and mortars. MRL has therefore been tasked (ARM 84/016) to investigate the feasibility of designing/developing a low cost practice projectile for the M198 155 mm howitzer using local production facilities.

The work described in this report was concerned with production processes and costs associated with the manufacture of shell bodies and the use of various shell fillings. The aim was to review those processes normally required to manufacture shell bodies suitable for filling with high explosive and to identify which processes might not be necessary for the manufacture of shell bodies suitable for practice projectiles.

Various body designs for unfilled shell were assessed to evaluate further cost reductions. For convenience, computer predictions to assess their areoballistic performance were carried out utilizing designs fitted with an L32A1 fuze and a spotting charge.

Shell bodies of 155 mm calibre were not available for experimental spotting charge trials. However the feasibility of using small amounts of high explosive and flash, noise, smoke enhancement materials, just sufficient to rupture the projectile body and to provide the required aural and visual signatures, was examined using 105 mm M1 and M374A2 81 mm mortar bomb bodies.

2. ARMY REQUIREMENTS

The Army task requested MRL to investigate the feasibility of designing and producing a low cost 155 mm practice projectile to meet the specified requirements. The projectile must:

- (a) explode to produce a noise audible to 7000 metres under standard meteorological conditions,
- (b) produce a smoke signature visible (line of sight) to 8000 metres with a 10 Knot breeze blowing in the vicinity of the impact point,
- (c) ballistically match the HE service projectile,
- (d) be able to be fitted with a PD fuze with the same fuze setting procedure as the service PD fuze, and
- (e) be able to be fitted with a time fuze with the same fuze setting as the service time fuze.

In addition MRL was also requested to:

- (1) investigate the cost benefits/penalties associated with the use of a purposed designed 155 mm practice projectile, and

- (2) advise on the probable establishment of manufacture and unit costs of purpose designed 155 mm practice projectiles.

3. CONCEPTS CONSIDERED

As a precursor to any cost studies, a number of concepts considered suitable for use as practice projectiles were assessed. Existing practice projectiles such as the UK L16A1 indicator projectile, based on the L15A1 HE projectile, and the US M804 were considered not suited to Australian requirements. The design of the M804 was based on the M107 HE and obviously has similar disadvantages to those previously discussed above. Little information was available on the British L16A1 projectile, it appears however that the projectile did not meet user requirements and its use was considered limited.

In considering practice projectile configurations, emphasis was placed on those concepts which, if used during manoeuvres and training exercises, would closely simulate phenomena such as, fire report, muzzle flash (both dependent on the propellant used), flash, smoke and noise signatures at the target, range capabilities and the aeroballistic performance of the operational projectile.

3.1 Projectiles Filled with High Explosive Substitute (HES)

The use of HES as a replacement for the HE filling in shells is perhaps the most convenient means of ensuring that an inert shell, fitted with an operational fuze, would ballistically match the operational projectile. Depending upon its formulation, HES can be cast or pressed into the shell body using standard production procedures. The density of HES can be tailored to meet specific requirements, but is usually used at a density of approximately 1.65 g/cm^3 , which simulates a composition B filling. Navy use HES filled 4.5 inch projectiles to train their gun crews [1,2] while Army use HES filled 81 mm practice mortar rounds. Production procedures for filling empty shell bodies with HES are fairly well established and the method chosen would depend upon the numbers required to meet service orders. For example, the HES filled 4.5 shell is filled manually because of the small number required. However, for larger production runs, automated filling lines would be feasible and could be established.

Applying existing HES filling technology to the 155 mm projectile would be a low risk procedure. The resultant projectile would have comparable mass, centre of gravity and inertial properties to the operational projectile, and hence similar flight characteristics. Careful control of the final mass would necessitate little if any change to the FACE software or range firing tables currently used for the operational L15A1 HE projectile.

The signature at the target could be produced by inclusion of a bursting/spotting charge which could form an integral part of the fuze or be added to the shell as a supplementary charge.

3.2 Hollow Shell Practice Projectile

The use of a hollow shell practice projectile containing a pyrotechnic or explosive charge to produce a signature upon impact is not a new concept. The US developed such a projectile, the M804 [3], to comply with US environmental constraints which called for a significant reduction in both noise and the ground shock which was produced when operational M107 HE filled 155 mm projectiles were used for training and practice. The M804 contains a smoke composition only and, when ignited, smoke is emitted through four vent holes at the base of the shell. Little or no noise is produced. Army suggested that these projectiles were not suited to their training requirements as the signature produced was not comparable to the operational projectile and because the projectile was not designed to break up upon impact. It could therefore be confused with an unexploded operational projectile resulting in potential range clearance problems.

In typical hollow shell configurations, the explosive or substitute filling is eliminated and the weight loss compensated for by selectively increasing the wall thickness of the shell (thereby the mass) whilst keeping the external dimensions identical to those of the operational projectile. Selective adjustment of the mass distribution in this manner ensures that the mass and centre of gravity of the hollow shell are similar to those of the high explosive service projectile. Adjustment of the mass distribution can alter inertial properties, the significance of which can be readily determined by assessing the aeroballistic performance of the designs.

The three hollow shell concepts (Figs 1a, b, c) were derived by modifying scaled L15A1 drawings. Masses and centres of gravity were determined by digitizing points along the cross section of the resultant internal profiles using specially developed computer software [4]. Three basic configurations were produced with masses and centres of gravity similar to those of the L15A1 projectile. For convenience, all configurations were modelled with the L32A1 fuze and a 200 g spotting charge which was attached directly to the base of the fuze. In concept 1 (Fig 1a) the additional mass was restricted to the centre section of the shell body, in concept 2 (Fig 1b) the additional mass was distributed in the regions significantly fore and aft of the shell body and in concept 3 (Fig 1c), the wall thickness was increased uniformly around the internal cavity of the shell body.

3.2.1 Assessment of Aeroballistic Performance of Hollow Shell Concepts

Proof and Experimental Group, Logistic Command Melbourne carried out computer predictions on various hollow shell concepts, based on data supplied. For all concepts considered the external dimensions were the same as the L15A1 HE projectile. Specifically they were asked to:

- (a) mathematically model the internal and external ballistic performance of the hollow shell concepts (Figs 1a, b, c) when propelled by standard L15A1 charges,
- (b) estimate the flight stability characteristics of the hollow shell configurations when launched at the L15A1 firing table conditions, and

(c) estimate the extent of ballistic mismatch between the three concepts.

For a specific concept, e.g. concept 1, a number of designs were produced in which the mass of the hollow shell ranged between ± 2 kg from that specified for the L15A1 projectile. These were labelled 1(A), 1(B), etc.

The data in Table 1 applies to those configurations in which the mass and centre of gravity deviated only marginally from that specified for the L15A1 projectile, but in which there was a marked variation in the inertial properties.

TABLE 1

Concept	Mass (kg)	Centre of Gravity (distance from base) (mm)	Mass Moments of Inertia kg m ²	
			Roll	Pitch
1(D)	43.5	298.9	0.169	1.74
2(E)	43.4	298.3	0.152	2.20
3(G)	43.5	303.4	0.163	2.04
L15A1 (filled)	43.4	299.4	0.148	1.91

The data in Table 2 applies to those configurations in which there was a marked difference in both the mass moment of inertia and mass but little variation in the centres of gravity.

TABLE 2

Concept	Mass (kg)	Centre of Gravity (distance from base) (mm)	Mass moments of Inertia kg m ²	
			Roll	Pitch
1(B)	45.6	301.2	0.175	1.79
1(F)	42.0	296.2	0.164	1.71
2(C)	42.1	298.5	0.150	2.20
2(F)	43.6	297.9	0.153	2.20
3(A)	42.1	300.9	0.159	1.98
3(D)	44.9	305.7	0.167	2.09
L15A1 (filled)	43.4	299.4	0.148	1.91

The flight stability of a projectile is normally described by both the gyroscopic and dynamic stability factors [5]. However, for a preliminary assessment such as this, a good indication of the aeroballistic stability of the hollow shell concepts was obtained by considering the gyroscopic stability factor only. Using this approach the factors which describe flight stability were greatly simplified to those listed below.

- (a) The projectile inertia ratio, given by the expression

$$I_R = I_{(\text{roll})}^2 / I_{(\text{pitch})}$$

where I is the mass moment of inertia described by the subscripts.

We can normalize the result of this equation and subsequently compare the inertia ratio of the hollow shell concepts to that of the L15A1 projectile by:

$$I_N = I_R(\text{hollow shell}) / I_R(\text{L15A1})$$

Any gain or loss of stability in the experimental model is reflected in a resultant value of greater or less than unity.

- (b) The square of the projectile spin rate (a function of the muzzle velocity and rifling twist).
- (c) The magnitude of the aerodynamic overturning moment coefficient. This parameter is determined by the projectile shape and the position of the centre of gravity.

As external profiles of all three hollow shell concepts (Tables 1 and 2) were identical to that of the L15A1 projectile we would expect their drag coefficients to be the same. Similarly we would expect little difference between the aerodynamic overturning coefficients of the hollow shell concepts and the L15A1, as the variation between their respective centres of gravity is minimal.

Normalized inertia ratio values are presented in Table 3. Values for concept 2 are all less than unity, indicating that a projectile of this design would be less stable during flight than the L15A1 HE projectile. This feature coupled with the likelihood that a shell body of this type would experience unacceptably high stresses during launch because of the manner in which the mass is distributed, makes concept 2 unacceptable. For these reasons this concept was not considered further.

TABLE 3

Concept	I_{roll} (kg m ²)	I_{pitch} (kg m ²)	I_{roll}^2/I_{pitch} (I_R) (kg m ²)	Normalized inertia ratios (I_N)
1B	0.175	1.79	0.017089	1.49
1D	0.169	1.74	0.015956	1.39
1F	0.164	1.71	0.015729	1.37
2C	0.150	2.16	0.010417	0.91
2E	0.152	2.20	0.010502	0.92
2F	0.153	2.20	0.010640	0.93
3A	0.159	1.98	0.012768	1.11
3D	0.167	2.09	0.013344	1.16
3G	0.163	2.04	0.013024	1.14
L15A1 (HE, Filled)	0.148	1.91	0.011468	1.00

Conversely, hollow shell concepts 1 & 3 would have good flight stability as the values for their normalized inertia ratio are greater than unity. The increase in the inertia ratio in concept 1 is due to the mass being concentrated about the centre of the shell body. This could result in what is termed an 'overstable' projectile. Mass distributed in this manner effectively spin stabilizes the projectile during flight and, as a result, the nose may never dip down sufficiently to keep pace with the dipping trajectory, causing the shell to land substantially base first [6]. Work to date indicates that inertia ratios up to 1.49 would be acceptable and therefore both concepts 1 and 3 warrant further study.

Other factors which could prevent a hollow projectile from matching the aeroballistic performance of the L15A1 projectile would be variations in the muzzle velocity and range due to mass variations of the projectile. Provided the mass of the projectile is maintained within the specified limits of ± 0.5 kg, then current L15A1 range firing tables and FACE software could be used.

For those hollow shell concepts in which the weight of the projectile lies outside the ± 0.5 kg specified for the L15A1 projectile, modifications to both the range firing tables and FACE software would be necessary to compensate for the mismatch in aeroballistic performance. If overseas equipment and software were to be used, then the generation of the appropriate ballistic data and software for such a projectile would be an expensive exercise. More importantly, variations in weight of the projectile outside that specified could result in a more severe launch environment,

thereby subjecting the howitzer and/or projectile to unacceptable stresses. The consequence of this would require further study.

3.3 Projectiles Containing Alternative High Explosive Filling

TNT has been suggested as being a suitable alternative filling to the HNS modified Composition B used in the L15A1 projectile. It is currently used as the high explosive filling in the US manufactured 155 mm M107 HE projectile. Projectiles filled with TNT would have similar flight characteristics to the L15A1 HE projectile as the cast densities of both fillings are comparable. The penalty of using an alternative high explosive filling other than TNT would have to be weighed against the safety aspects associated with such a projectile. Any high explosive chosen would have to be relatively insensitive to enable it to survive the setback forces experienced by the projectile when launched at higher propellant charge weights.

The quality of the high explosive filling would need close scrutiny. The British use HNS modified Composition B filling to achieve a cast filling devoid of cavities and cracks, which they claim is necessary to prevent premature detonation of the high explosive filling when the projectile is fired. The use of a filling other than TNT would require some development work to ensure good quality cast fills could be obtained.

4. SPOTTING CHARGE TO PRODUCE SIGNATURE AT IMPACT POINT

The feasibility of a practice round based on either the hollow shell concept or the HES filled round depends on the viability of using a spotting charge to produce an adequate signature upon impact. Such a spotting charge could contain just sufficient high explosive to burst the shell body and a composition containing smoke, noise and flash enhancement materials. The spotting charge could be an integral part of the fuze or it could be added as a supplementary charge to the shell body. Ideally the signature produced should simulate that of the operational projectile. However, depending upon choice of materials, the spotting charge could be designed to give a range of signatures.

Early work to assess various spotting charges was restricted to the use of empty 105 mm shell and empty 81 mm mortar bodies as there were no L15A1 shell bodies available in Australia. These bodies were used as test vehicles in two spotting charge trials conducted in 1984 to demonstrate that a suitable impact signature could be achieved by using a small quantity of specially prepared spotting composition instead of the conventional high explosive.

The spotting charges (Table 4) were confined in a cardboard container which was fitted to the rear of an adapter. The adapter was then screwed into the shell or mortar body. Typical configurations are shown in Figs 2 and 3. The shell and mortar bodies were placed vertically on the ground and remotely initiated using an electric detonator. Observers were positioned (with line of sight) at distances ranging from 1 km to 4 km away from the impact area.

Generally, all spotting charge combinations assessed during the first trial gave good visual and audible signatures which were observed/heard from a distance of 2 km. The TNT/DYE composition produced a black smoke, attributed to the decomposition of the organic dye. The pyrotechnic smoke composition produced a bluish grey smoke which dispersed quickly. The red phosphorus and the TNT/AL produced the best signatures of the four combinations assessed, producing a good flash and noise output, together with a dense white smoke cloud. The flash in the TNT/Al charge was enhanced by the presence of aluminium.

Both configurations were subsequently retrialled using procedures similar to those adopted during the initial trial but with additional observers at 2 km and 4 km from the impact point. The results again confirmed the suitability of these materials to generate an acceptable signature since visual and sound observations were recorded at a distance of 4 km.

TABLE 4

Shell Body (mm)	Burster Charge		Spotting		Observations (noise at 1 km)
	Explosive	Mass (g)	Explosive	Mass (g)	
105	Service HE round (4 kg)				Greyish smoke, some flash, noise ~ 130 dB
105	CE	94	TNT/DYE	100	Black smoke, no discernible flash, noise ~ 119 dB
105	CE	66	TNT/AL	150	White smoke, flash, noise ~ 122 dB
105	CE	94	SR254A	100	Greyish smoke, no discernible flash, noise ~ 119 dB
105	CE	116	Red Phosphorus	100	Dense white smoke, flash noise ~ 120 dB
81	Service HE round (.8 kg)				Greyish smoke, some flash noise ~ 120 dB
81	CE	22	TNT/DYE	100	Black smoke, no flash, noise ~ 120 dB
81	CE	44	TNT/AL	100	Fair smoke output, flash, noise ~ 122 dB
81	CE	44	SR254A	100	Bluish grey smoke, no flash, noise ~ 114 dB
81	CE	44	Red Phosphorus	75	Dense white smoke, flash, noise ~ 120 dB

These field tests successfully demonstrated to the Army personnel present that using a spotting charge as a replacement for the high explosive filling was an acceptable alternative for the Army as an aid to the training of forward observers in gunfire support.

5. COST PENALTIES/BENEFITS ASSOCIATED WITH A PRACTICE ROUND

At present Australia does not have the production capability or the technical data base to manufacture the L15A1 HE projectile. Therefore the cost associated with the production of a 155 mm practice projectile based on the L15A1 was difficult to ascertain and many of the costs obtained were only estimates.

As a first step in assessing the cost penalty/benefit associated with the practice round, processes and costs associated with the manufacture and filling of a shell were reviewed.

5.1 The Shell Body

An examination of the shell production facilities at Ordnance Factory Maribyrnong (OFM) was undertaken to identify those areas in the production of shell bodies which could be either eliminated or modified to reduce costs. OFM production includes the manufacture of 4.5 inch, 5 inch and 105 mm shell bodies. Tentative cost estimates indicated that the L15A1 shell body could be produced for \$250-\$350 (1984 estimates) utilizing an existing production line which would provide a low production rate at low capital cost [7].

The introduction of a practice projectile which used the same empty body as the operational projectile, could result in increased production runs with the resulting economies of scale possibly leading to cheaper bodies for both the HE and the practice round.

5.1.1 Material Selection

Selection of an appropriate steel for HE shell bodies involves a compromise between desirable fragmentation steel characteristics and minimum mechanical properties to ensure safety during launch. For a practice projectile, a high fragmentation steel is unnecessary and indeed may be undesirable if only limited breakup of the projectile is required at the target, or in the case of accidental functioning. Consequently, it may be possible to use a less expensive grade of steel in the manufacture of bodies for practice projectiles.

5.1.2 Heat Treatment

As indicated above (5.1.1), all projectile bodies must be sufficiently strong to survive the stresses experienced during launching. The bodies of many service projectiles are heat treated by quenching and tempering to achieve this but such operations might not be necessary for some practice projectile bodies. For example, hollow shell configurations in which it is possible to increase wall thickness sufficiently to compensate for the reduction in mechanical properties which occurs when quenching and tempering operations are eliminated.

Heat treatment accounts for approximately 5% of the total production time of a shell body and elimination of this process would result in a real reduction in overall cost.

5.1.3 Shot Blasting

Shot blasting followed by occasional machining rectification is used to clean and finish the shell cavity to ensure that it is suitable for filling with HE.

The acceptance of an "as forged" cavity would eliminate the need for shot blasting and rectification. This would only be viable if the high explosive filling was replaced by HES or if the practice projectile was manufactured using the hollow shell concept.

Shot blasting and rectification account for approximately 3% of the total production time.

5.1.4 Base Plate

The base plate on a projectile is an incorporated safety feature to prevent propellant flash igniting the HE filling through longitudinal defects or occlusions that may not have been detected in the shell body during inspection. The requirement for a base plate could be eliminated if the practice projectiles contained HES or if the spotting charge used with the hollow shell concept was suitably containerized.

Deletion of a base plate would save approximately 2% of the total production time.

5.1.5 Inspection

Service inspection of the shell body during manufacture accounts for approximately 10% of the shell production time. Each operational projectile requires 100% inspection before the body can be qualified for filling with a high explosive material. If an HES filled shell or a hollow shell was to be used, then internal inspection of the forged cavity would not be required.

Alternatively, the number of shell bodies undergoing complete inspection during a production run could be reduced to the number required to be filled with high explosive. For example, in a total production run of 10,000, 10% are required for operational use and the remainder for the manufacture of HES filled practice projectiles. Inspection could then be modified so that only 1 in 10 shell bodies receive full inspection and, providing they pass, are set aside for filling with high explosive. The remainder could be inspected as per practice projectile requirements.

5.2 Shell Filling

The choice of filling depends on the desired end effect. For a practice projectile, fragmentation was considered to be unimportant, it only being necessary to produce an operationally acceptable smoke, noise and flash signature with sufficient rupturing of the shell body to minimize the probability of the spent round being mistaken for an unexploded projectile.

5.2.1 HES Filled Projectile

It has been suggested that Army's apprehension in using a practice projectile containing a HES filling was based on the cost of the 4.5 inch practice projectile manufactured for the Royal Australian Navy. These projectiles were filled manually because of the small numbers required and as a result the manufacture of the 4.5 inch practice projectile was relatively expensive.

The cost of filling a projectile with HES depends on the numbers required. With larger numbers, automated lines could be used, therefore the cost of filling a projectile with HES should be less than filling it with high explosive. The cost differential would perhaps be more obvious with the L15A1 projectiles which are filled with a HNS modified Composition B which is a particularly time consuming and complicated process.

Although some inspection would still be necessary, inspection requirements for an HES filled round would be less stringent than for projectiles containing high explosive. The inspection process would therefore be less labour intensive and less costly.

An HES filled shell body could be stored as an inert projectile with similar cost savings to those claimed for the US M804 practice projectile. As an approximation, the storage cost of operational projectiles is 20% of the cost of all the explosive items contained in the projectile. Safety requirements for in-gun proofing would also be less severe, as the likelihood of inbore prematures would be minimal.

5.2.2 Hollow Projectile

The use of a hollow shell as a practice projectile would have the same cost benefits as those mentioned for the HES filled projectile, with the added advantage that no filling would be required. This concept would

dispense with the need for a separate HES production facility and filling line. Additional inspection of mass and centre of gravity, necessary for HES projectiles, would not be required as this inspection would have been carried out at the shell production stage.

Opposed to these benefits some initial costs would be incurred in modifying the tooling necessary to forge the shell cavity. This would be a relatively low risk procedure and should involve only minimal costs.

5.2.3 TNT Filled Projectile

It has been claimed that savings of up to \$80 (1983 estimates) could be achieved by replacing the HNS modified Composition B filling currently used in the L15A1 with a cheaper HE filling such as TNT.

Any initial savings relating to choice of filling would be offset by costs due to:

- (a) the development work necessary to establish a suitable filling process to give the high quantity fill claimed as being necessary to prevent in gun prematures,
- (b) safety in-gun proofing,
- (c) production procedures necessary to manufacture shell bodies for HE quality fill,
- (d) inspection requirements, and
- (e) storage and transport.

Overall production costs would be similar to that of L15A1 HE projectile and therefore the choice of using a projectile filled with TNT or an alternative high explosive would not seem to be a viable proposition.

5.3 Fuze

Fuzing aspects were not considered in this report, however it was recognised as being an area where cost savings can be achieved. The use of a low lethality spotting charge incorporated into a HES or hollow shell offers potential for some cost savings by use of a cheaper fuze.

Cheaper fuzes, possibly incorporating plastic components could be feasible. These would be significantly lighter than the L32A1 fuze used to model the hollow shell, and would therefore affect the position of the centre of gravity and the inertial properties. In a hollow shell these variations could be compensated for by selective adjustment of the mass distribution within the shell body at the initial design stage. Compensating for these variations in the HES filled projectile would require developmental work to determine the most practical and economical approach.

5.4 Spotting Charge

Spotting charges have been successfully incorporated into existing practice munitions such as the BDU 33 practice bomb and the 4.5 inch naval bombardment round [1,2]. In these applications the spotting charge package was a relatively simple design and inexpensive to produce. A wide range of explosive/pyrotechnic materials can be utilized to give operationally acceptable signatures at the target. The choice of materials would depend on service requirements.

The design of a spotting charge package for the 155 mm practice round would depend on whether it is to be used in an HES filled projectile or a hollow shell. In the latter case, the package would have to be sufficiently rugged to enable it to survive the launch accelerations experienced by the shell. If used with an HES filled projectile the design constraints could be eased, as the spotting charge package would be supported, to a large extent, by the inert filling.

Although development work is still necessary to optimize the signature produced, it is expected that a suitable spotting charge package could be manufactured relatively cheaply.

6. CONCLUSION

The study has shown that it is feasible to produce locally a low cost 155 mm practice projectile based on the British L15A HE projectile, with the hollow shell concept or 155 mm shell bodies filled with HES being the most promising candidates at this stage. Practice projectiles of either type could easily be fitted with a spotting charge to produce the required signature at the target.

Manufacturing processes, normally used in the production of shell bodies suitable for filling with high explosives, such as shot blasting the internal cavity, heat treatment, full inspection and inclusion of a base plate, could be modified or eliminated by adopting either of the above configurations. Individually these cost savings may be small but taken together they constitute a significant saving to the cost of a shell body suitable for use as a practice projectile.

Storage and transport requirements applying to high explosive filled projectiles would not be applicable because practice projectiles without fuzes would be inert. Further savings would therefore be achieved.

Practice projectiles of either design could be produced to match the ballistic characteristics of the L15A1 HE projectile which would allow existing L15A1 FACE software and range firing tables to be used.

A practice projectile based on the hollow shell design would have the added advantage over the HES filled projectile of not requiring any inert filling. This would realize additional cost savings over an HES filled round by dispensing with the need for (i) an HES production facility; (ii) a dedicated HES shell filling line and (iii) the additional inspection that would be required for a HES filled projectile. It is therefore recommended that further work be undertaken to develop a practice projectile based on the hollow shell concept, particularly concepts 1 and 3 (Figs 1a, 1c). The initial phase of any additional work should be directed at carrying out stress analysis of the preferred concepts to determine the significance of the varied mass distribution on the forces acting on the shell body and driving band and to determine the internal ballistics.

The use of a cheaper high explosive filling such as TNT does not seem viable or cost effective since essentially the same production procedures and storage/transport constraints applying to projectiles filled with high explosive would still be necessary. Additional costs would also be incurred in developing the high explosive filling capability necessary to achieve the required high quality of filling.

It has also been demonstrated that a spotting charge can be produced which will give good visual/audible signatures at distances of up to 4 km. Spotting charges (Figs 2 & 3) can be fitted directly to the fuze or incorporated into the practice projectile as a separate discrete package.

The unit cost of a practice projectile was not easy to determine as manufacturing and filling facilities for the L15A1 HE projectile have not as yet been established or thoroughly assessed, therefore any cost estimates would be tentative. The adoption of either the hollow shell concept or the HES filled practice projectile would realize significant cost reductions for reasons already stated and savings of between 30% and 50% would not be unrealistic. Although the data obtained in this report applies to the development of a low cost 155 mm practice projectile, the same approach may be used to develop practice munitions for other calibre guns and mortars.

It may be necessary to accept a trade off in the overall cost saving associated with the manufacture and use of a purpose designed practice projectile due to the possible increase in the unit cost of the operational HE filled projectile. This increase would be attributed to the smaller production runs necessary to satisfy service requirements.

The two configurations assessed satisfy most Army task requirements (Section 2). One requirement specified that the practice round should ballistically match the operational round. While this may be a desirable feature it should not necessarily be a mandatory one. Any decrease in range of the practice projectile attributed to variations in the inertial properties would not necessarily be detrimental to the Army training program, provided that the mass variation remained within the range specified for the operational round. Realistic training of gun crew and firing officers could still be achieved by suitable modification of the FACE software such that the practice projectile would still appear to simulate the operational round. Similarly training of forward observers would not be compromised by using

short range practice projectiles as the signature produced upon impact would be more important than the range attained.

7. EXPERIMENTAL

7.1 Amount of High Explosive Necessary to just Rupture Shell or Mortar Body

The amounts of high explosive necessary to rupture the 105 mm shell and 81 mm mortar body were determined experimentally using a similar explosive package to that shown in Fig 2, the exception being that only high explosive pellets were loaded in the cardboard tubing attached to the adapter. The adapter was then screwed into the shell or mortar body and the spotting charge initiated using an electric detonator. This procedure was repeated, altering the mass of high explosive for each successive shot until the body just fragmented. An unfilled 105 mm body required 66 g high explosive and the 81 mm mortar body required a maximum of 22 g (lower charge weights were not assessed).

7.2 Materials used to Manufacture the Spotting Charges

7.2.1 TNT was obtained in biscuit form from existing stock held at Materials Research Laboratories (MRL). The biscuits were crushed using a wooden roller and the fraction passing through a 420 μ m sieve was used to prepare the TNT/dye and TNT/aluminium formulations.

7.2.2 The dye used in the TNT/dye formulation was red dye to specification CS 5310.

7.2.3 The aluminium powder used in the TNT/aluminium formulation was ex MRL stock. This was graded by sieving, with the fraction passing through a 420 μ m sieve but retained on a 250 μ m sieve being used in the formulations.

7.2.4 The tetryl used in shell rupture studies was in a powdered form and was production stock obtained from the Explosives Factory Maribyrnong.

7.2.5 The pyrotechnic smoke composition was SR 254A.

7.3 Formulation of Spotting Charge Composition

7.3.1 The TNT/dye formulation contained:

TNT	75%
Dye	25%

7.3.2 The two TNT/aluminium compositions prepared, contained:

7.3.2.1	TNT	50%
	Al	50%

7.3.3 The pyrotechnic white smoke composition SR 254A contained:

calcium silicide	10%
hexachloroethane	45%
zinc oxide	45%

7.4 Preparation of Spotting Charge Compositions

All spotting charge compositions were mixed by passing weighed portions of the respective ingredients four times through a 600 μm sieve.

The materials used to make up the pyrotechnic composition were first sieved to remove the larger aggregates; the calcium silicide through a 250 μm sieve and the hexachloroethane and zinc oxide through a 420 μm sieve.

Two percent insulating oil (BS 148) was added to stabilized red phosphorus to improve its binding properties.

7.4.1 Preparation of Pellets

Solid pellets of tetryl, TNT and TNT based compositions (40 mm diameter) were prepared by consolidating weighed amounts (22 g for tetryl and 25 g or 50 g for TNT and the TNT based compositions) at 9×10^3 kgf using a Marico press. The density of the pellets ranged between 1.60 - 1.66 g/cm³.

Annular pellets (40 mm OD and 6 mm ID) of both the pyrotechnic and red phosphorus composition were prepared using a pressing load of 9×10^3 kgf and 9×10^2 kgf respectively. The pellets weighed 25 g or 50 g and had densities ranging between 1.45 - 1.55 g/cm³.

7.5 Preparation of Spotting Charges

In all spotting charge configurations, except those containing red phosphorus, the pellets were loaded directly into cardboard tubing with each pellet butting directly against the other. Small pellets of PETN were placed into the central cavity of the annular pellets to ensure efficient ignition of the spotting charge composition.

In spotting charges using red phosphorus, care was taken to ensure that the red phosphorus was completely isolated from any high explosive materials. This was achieved by encasing the red phosphorus pellets into separate cardboard tubes and sealing the ends prior to their assembly into the main spotting charge.

8. ACKNOWLEDGEMENTS

The author gratefully acknowledges the advice and direction forwarded by Mr Peter Ramsay, Mr Frank Bristow for drafting assistance and providing scaled drawings, the Ordnance Factory Maribyrnong for supply of 105 mm and 81 mm shell bodies, often at short notice, and Mr Paul Buchler, Logistic Command Melbourne, for very helpful discussions and data concerning ballistic stability of the hollow shell concepts.

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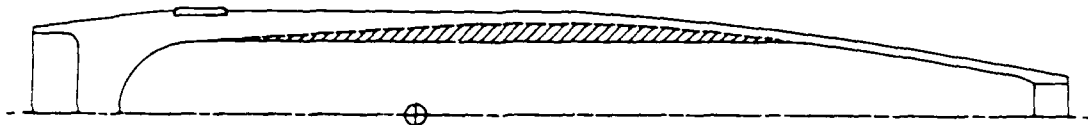


FIG. 1a Concept 1. Added mass restricted to centre section of the shell body.

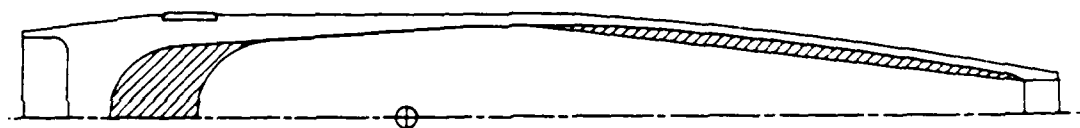


Fig. 1b Concept 2. Added mass distributed fore and aft of the shell body.

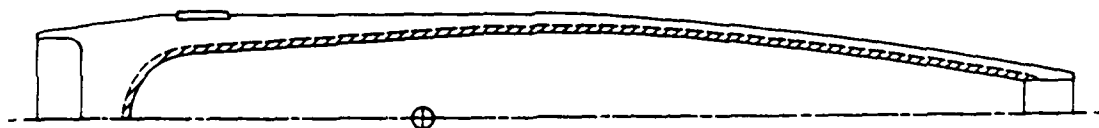


Fig. 1c Concept 3. Added mass distributed uniformly around the internal cavity of the shell body.

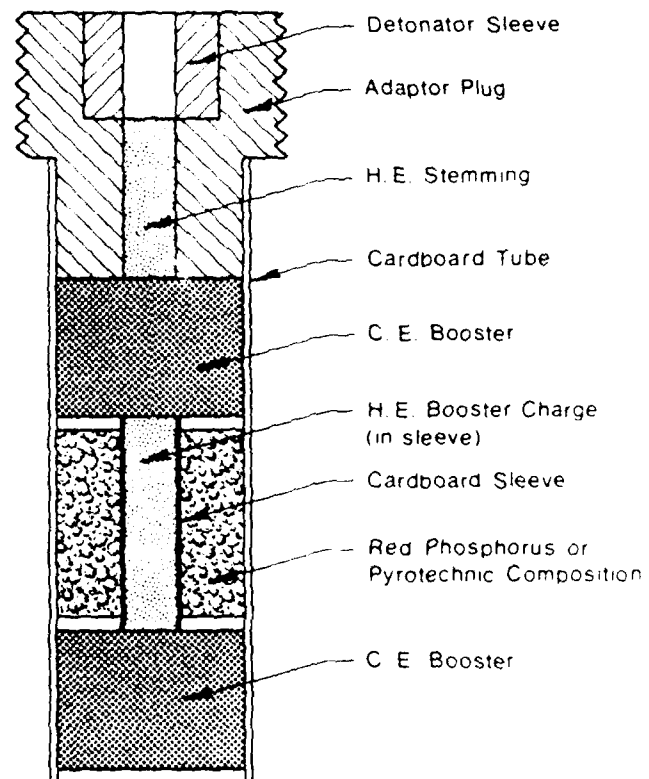


FIGURE 2 Spotting charge containing red phosphorus or pyrotechnic spotting compositions.

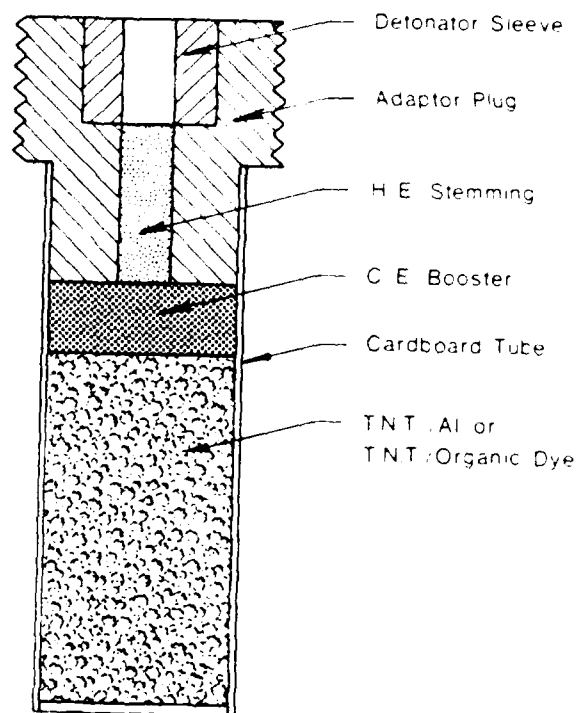


FIGURE 3 Spotting charges containing high explosives based spotting compositions.

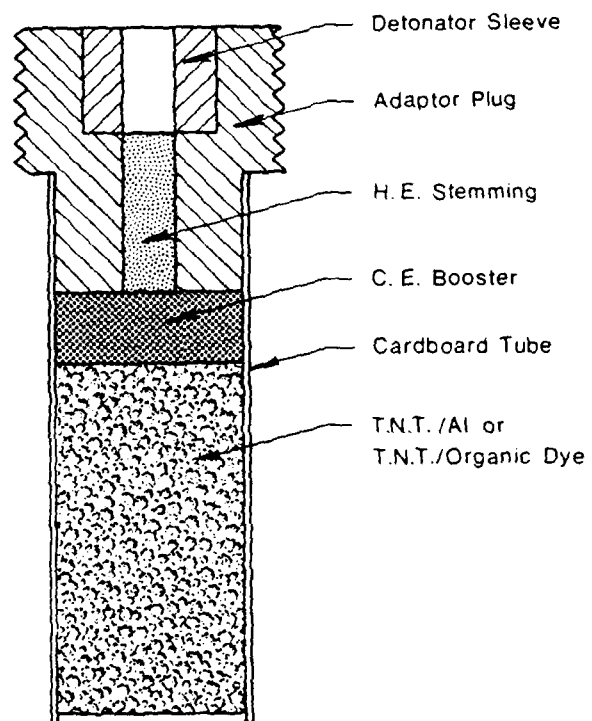


FIGURE 3 Spotting charges containing high explosives based spotting compositions.

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